

CAN ANALYTICAL CARTOGRAPHY SERVE AS A LINK BETWEEN CARTOGRAPHY AND GISCIENCE?

by

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ABSTRACT

In recent years some in the ICA have looked at the stated body of knowledge in GIScience, and have seen a need to link that work closer to the field of Cartography. This is because they see a need to link to such spatial theory and utilize it in the field of Cartography. It turns out that since the 1960s Tobler and many colleagues have developed the area of Analytical Cartography which includes many of these topics in spatial science. During the 1990s Goodchild and colleagues led an effort to expand the conceptual base of GIS into what is now called GIScience. After many years of development they have published a Body of Knowledge for GIScience. This paper will explore these areas and identify commonalities between them. This will form a basis for the discussion of how Analytical Cartography can serve as a vital link between the fields of Cartography and GIScience that some in the ICA see as a way of enhancing the field of Cartography and facilitating cooperation between the two fields in the future.

Keywords: Analytical Cartography, Cartography, GIScience, GeoSpatial Theory, Body of Knowledge

INTRODUCTION

In recent years some leaders in the International Cartographic Association (ICA) have looked at the stated Body of Knowledge in GIScience, (see Dibiase, 2006), and have seen a need to link to that work closer to the field of Cartography. This is because they see some of the theory they currently use in cartography is listed in this GIScience Body of Knowledge. More importantly, they also see a need to link more broadly to such spatial concepts and theory, and utilize them more widely in the field of Cartography. This was emphasized by Cartwright (2011, p. 82) when he said "...to help widen the Cartographic/GIScience knowledge base and skills into new segments of society...". Many of these concepts are already part of Analytical Cartography, and they may be used to help form a bridge between Cartography and GIScience.

One can examine the broad conceptual makeup of Analytical Cartography as shown in Figure 1. It shows that it is composed of five major disciplines:

- * Cartography
- * Mathematics
- * Computer Graphics
- * Image Analysis
- * Geography

They mix together in various ways to form the foundation for modern Analytical Cartography. Interestingly, it can be noted that GIScience uses many of these fundamental disciplines in similar ways, but perhaps in somewhat different combinations.

This paper will examine the content of Analytical Cartography and GIScience, and will explore these areas and identify commonalities between them. This will form a basis for the discussion of how Analytical Cartography can serve as a vital link between the fields of Cartography and GIScience that some see as a way of enhancing the field of Cartography, and facilitating cooperation between the two fields in the future.

ANALYTICAL CARTOGRAPHY

Modern Analytical Cartography was initially developed and named by Prof. Waldo Tobler where his goals were to "solve cartographic problems", and then in a quantitative analytical way "to capture this theory". His initial work on Geographic Map transformations (Tobler, 1961) led the way and provided great inspiration to fellow spatial scientists.

Over the years this work by Tobler and many other colleagues has blossomed into a wealth of analytical conceptual theory and concepts. The following list is an sample of the concepts and theory in analytical Cartography. Moellering's article (2000) reviews and summarizes the situation in much more depth with extensive references.

- * Geographical Map Transformations
- * Real/Virtual Map Transformations
- * Deep & Surface Structure
- * Nyerges Data Levels
- * Spatial Primitive Objects
- * Topological Data Structures
- * The Sampling Theorem
- * Spatial Semantics & Ontology
- * Spatial Neighborhood Operators
- * Spatial Frequencies
- * Spatial Fourier Theory
- * Spatial Information Theory
- * Spatial Fractal Theory
- * Critical Surface Features
- * Warntz Networks
- * Polygon Overlay Analysis
- * Irregular Neighborhood Operators
- * Resolution Elements - Resels
- * Volumetric Pycnophlactic Transformations
- * Map Generalization - 1,2,3-D
- * Shape Analysis
- * Spatial Data Models
- * Analytical Visualization
- * Spatial Data Standards

This list forms a representative, but not comprehensive, list of the concepts and theory in modern Analytical Cartography. However, it should provide the reader with a reasonable conceptual framework of the field.

GISCIENCE

During the 1990s Prof. Michael Goodchild and colleagues led an effort to expand the conceptual base of GIS into what is now called GIScience. His initial call was put forth at the 1990 Spatial Handling meetings in Zürich (Goodchild, 1990) where he wrote:

The papers at this conference address a set of intellectual and scientific questions which go well beyond the implications of its title. The paper reviews the topics which might be included in a geographic information science. Research on these fundamental issues is a better prospect for long term survival and acceptance in the academy than development of technical capabilities.

He proceeded to discuss the following fundamental topics for a prospective field of Geographic Information Science:

- * Data Collection & Measurement
- * Spatial Statistics
- * Theories of Spatial Data
- * Data Structures, Algorithms & Processes
- * Display
- * Analytic Tools.

Many in the field responded to his challenge, and the name GIScience, along with its broadened horizons, became established in the field. It has continued to flourish scientifically.

By the early 2000s questions arose as to what constituted GIScience on a more specific basis. After several years of effort under the auspices of the University Consortium for Geographic Information Science (UCGIS), a broadly-based committee developed a document that specified the Geographic Information Science & Technology Body of Knowledge (DiBiase, et.al., 2006). This GIS&T Body of Knowledge specified ten broad categories of spatial knowledge that were parts of GIScience. Of those, eight sections focused on the various aspects of scientific knowledge that are of interest in this discussion:

- * Analytical Methods
 - AM1 Academic & analytical origins
 - AM2 Query operations & query languages
 - AM3 Geometric measures
 - AM4 Basic analytical operations
 - AM5 Basic & analytical methods
 - AM6 Analysis of surfaces
 - AM7 Spatial statistics
 - AM8 Geostatistics
 - AM9 Spatial regression & econometrics
 - AM10 Data mining
 - AM11 Network analysis
 - AM12 Optimization & location-allocation modeling
- * Conceptual Foundations
 - CF1 Philosophical foundations
 - CF2 Cognitive & social foundations
 - CF3 Domains of geographic information
 - CF4 Elements of geographic information
 - CF5 Relationships
 - CF6 Imperfections in geographic information

- * Cartography and Visualization
 - CV1 History & trends
 - CV2 Data considerations
 - CV3 Principles of map design
 - CV4 Graphic representation techniques
 - CV5 Map production
 - CV6 Map use & evaluation
- * Design Aspects
 - DA1 The scope of GIS&T system design
 - DA2 Project definition
 - DA3 Resource planning
 - DA4 Database design
 - DA5 Analysis design
 - DA6 Application design
 - DA7 System Implementation
- * Data Modeling
 - DM1 Basic storage & retrieval structures
 - DM2 Data management systems
 - DM3 Tessellation data models
 - DM4 Vector & object data models
 - DM5 Modelling 3D, uncertain, and temporal phenomena
- * Data Manipulation
 - DN1 Representation transformation
 - DN2 Generalization & aggregation
 - DN3 Transaction management
- * Geocomputation
 - GC1 Emergence of geocomputing
 - GC2 Computational aspects & neurocomputing
 - GC3 Cellular automata
 - GC4 Heuristics
 - GC5 Genetic algorithms
 - GC6 Agent-based models
 - GC7 Simulation modeling
 - GC8 Uncertainty
 - GC9 Fuzzy sets
- * Geospatial Data
 - GD1 Earth geometry
 - GD2 Land partitioning systems
 - GD3 Georeferencing systems
 - GD4 Datums
 - GD5 Map Projections
 - GD6 Data quality
 - GD7 Land surveying & GPS
 - GD8 Digitizing
 - GD9 Field Data Collection
 - GD10 Aerial imaging & photogrammetry
 - GD11 Satellite & shipboard remote sensing
 - GD12 Metadata, standards, and infrastructures.

If one examines the more detailed subsections encompassed within the 60 sections listed here, all of the above representative topics from Analytical Cartography can be found somewhere within the 270 topical Subsections listed in the GIS&T Body of Knowledge. This means that there are many scientific linkages between Analytical Cartography and GIScience.

DISCUSSION

The preceding information above demonstrates an extensive number of linkages between Analytical Cartography and GIScience. All 24 of the example topics in the Analytical Cartography list above can be mapped in some way into the more-detailed GIScience Body of Knowledge. Since Analytical Cartography is a solid part of the field of Cartography, it is clear that the mapping of these topics into the GIScience Body of Knowledge can form a conceptual and theoretical bridge between the two areas. Hence the desire of the ICA leadership, as expressed in recent ICC conferences, to link Cartography more closely to GIScience can be accomplished rather handily. Hence the expressed desire by Cartwright (2011), and many others, has a rather good chance of success.

This still leaves the question of the field of Cartography formulating a formal Body of Knowledge on its own. This question is separate from developing better scientific linkages with GIScience. Rather it has to do with those who do research in the field of Cartography to have a better understanding of all of the components in the field itself, and the intellectual base on which it rests. Buchroithner and Fernández (2011) recognized this situation and general need when they said:

So far, cartography has experienced only little theoretical development. ... If cartography wants to reach a wide-accepted more prominent scientific status, it needs, in addition to its well-developed and up-to-date methodology, to create its own updated epistemological basis.

Over the last several years, the leadership of the ICA has worked to produce a Research Agenda for the field (Virrantaus, Fairbairn and Kraak, 2009). The resulting ICA Research Agenda is enlightening as it now stands, but overall it is rather inward looking because it only examined the work of the ICA Commissions. However, to serve a wider utility, it should be more outward looking and take into account not only current research work in the field, but also identify unfulfilled areas in the field. Several, including Moellering (2001) have recommended items for the ICA Research Agenda.

Moellering also recognized that in order to more clearly understand the research agenda one must have a clearly specified body of knowledge to form a basis for the assessment. Hence his ICC 2011 Paris paper, and later article (Moellering, 2012), called for the development of a formal Body of Knowledge for the field of Cartography. This is a separate discussion from the main thrust of this paper, but the development of a Body of Knowledge for Cartography would assist with the bridging process with GIScience.

SUMMARY AND CONCLUSIONS

This paper has taken a close look at the broad conceptual and theoretical content of Analytical Cartography and GIScience. The 24 listed items of concept and theory in Analytical Cartography and the 60 topics that come out of the eight sections in the GIScience Body of Knowledge provide ample detail to make a comparison and assessment of the two fields. The result shows a good scientific congruence of the concepts and theory between the two fields.

Since Analytical Cartography is a subfield of Cartography, it is clear that Analytical Cartography can serve as bridge between the main field of Cartography and GIScience. This provides the ICA leadership with more confidence to pursue William Cartwright's goal to strengthen the linkages between Cartography and GIScience.

A second realization that emerges from the discussion here is the clear need for the ICA to develop a formal Body of Knowledge that encompasses all aspects of the entire field of Cartography. This will strengthen the whole field in that it more clearly and concisely defines Cartography so that specialists working in a particular part of the field can more clearly understand other parts of the field. It also will provide a well organized scientific and technical whole for any outside the field to understand more clearly. There is a significant need for the ICA more forward with this effort to develop a formal Body of Knowledge for the field of Cartography.

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